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Stark broadening of Xe VIII spectral lines

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ABSTRACT

Stark broadening parameters have been calculated for 60 spectral lines of Xe VIII, for broadening by electron, proton, and He III impacts. For calculations, the semiclassical perturbation approach in the impact approximation has been used. The widths and shifts are provided for temperatures from 20 000 K to 500 000 K and for an electron density of 10^{17} cm^{-3}. Obtained results have been used to study the influence of Stark broadening on spectral lines in DO white dwarf atmospheres and it has been found that exist broad layers where this broadening mechanism is dominant in comparison with thermal Doppler broadening.

Key words: atomic data – atomic processes – line: formation.

1 INTRODUCTION

In many astrophysical plasmas Stark broadening of spectral lines is very important or at least non-negligible and should be taken into account (Beauchamp, Wesemael & Bergeron 1997; Popović et al. 2001b; Dimitrijević 2003; Dimitrijević & Sahal-Bréchot 2014). It is also important for laboratory plasmas (Konjević 1999; Torres et al. 2006), inertial fusion plasma investigation, modelling and analysis (Griem 1992), laser produced plasma analysis and diagnostics (Gornushkin et al. 1999; Sorge et al. 2000), and for various technological plasmas and applications, as e.g. for laser welding and piercing (Hoffman, Szymański & Azharonok 2005; Dimitrijević & Sahal-Bréchot 2014), light sources based on plasma, and laser design and developing (Csillag & Dimitrijević 2004; Dimitrijević & Sahal-Bréchot 2014).

In astrophysics, Stark broadening is usually the principal line broadening mechanism for white dwarfs, pre-white dwarf stars, and post-AGB (Asymptotic Giant Branch) stars. Popović, Dimitrijević & Tankosić (1999b), Tankosić, Popović & Dimitrijević (2003), Milovanović et al. (2004), Simić et al. (2006), Dimitrijević et al. (2011), Dufour et al. (2011), Larbi-Terzi et al. (2012), Simić, Dimitrijević & Sahal-Bréchot (2013) and Simić, Dimitrijević & Popović (2014) studied the influence of Stark broadening in DA and DB white dwarf atmospheres and demonstrated its importance. Hamdi et al. (2008) reported the results of a study of the influence of Stark broadening in DO white dwarf atmospheres, on the example of Si VI lines, and shown its dominance in broad region of the atmosphere. Additionally Hamdi et al. (2014) demonstrated on the example of Ar III lines, the importance of Stark broadening in sdB (subdwarf B) star atmospheres.

For temperatures greater or around 10 000 K hydrogen is mainly ionized and Stark broadening is the principal pressure broadening mechanism (Griem 1974), as is the case for A and late B stars, where it must be taken into account for investigation of their atmospheres, which has been analysed for example in Lanz, Dimitrijević & Artru (1988), Popović, Dimitrijević & Ryabchikova (1999a), Popović, Milovanović & Dimitrijević (2001a), Popović et al. (2001b), Dimitrijević et al. (2003a,b), Tankosić et al. (2003), Dimitrijević et al. (2004), Milovanović et al. (2004), Dimitrijević et al. (2005, 2007), Simić et al. (2005a), Simić et al. (2005b) and Simić, Dimitrijević & Kovačević (2009). For example Popović et al. (2001b) demonstrated that, in the case of A-type star atmospheres, the inclusion of Stark broadening can change the equivalent widths by 10–45 per cent, so that abundances, determined neglecting this mechanism, may be with significant errors.

With the development of satellite-born astronomy, earlier astrophysically insignificant data on trace elements become more and more important. So, recently, Werner et al. (2012) reported on the first detection of krypton and xenon in a white dwarf. They analysed spectrum of DO white dwarf RE 0503-289 ($T_{\rm eff}$ = 70 000 K, Dreizler & Werner (1996)), obtained by FUSE (Far Ultraviolet Spectroscopic Explorer) and found 11 Xe VI and Xe VII lines. As shown by Hamdi et al. (2008), Stark broadening is dominant line broadening mechanism in larger part of a DO white dwarf atmosphere.

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In hot, chemically peculiar stars, where Stark broadening is not negligible, Xe II lines were found half a century ago (Bidelman 1962) and Dworetsky, Persaud & Patel (2008) found extreme overabundance of Xe in Hg-Mn stars, as a consequence of radiative-driven diffusion (Werner et al. 2012). In such stars, data on Stark broadening of Xe VIII spectral lines may be of interest for the modelling of subphotospheric layers where Stark broadening is of particular importance.

For modelling hot star atmospheres or for deriving accurate atmospheric parameters, a large number of atomic data, including Stark broadening parameters is needed (Dufour et al. 2011). Also Rauch et al. (2007) underlined that accurate and as much as possible complete Stark broadening tables for large number of atoms and ions are of crucial importance for sophisticated analysis of stellar spectra by means of Non Local Thermodynamic Equilibrium (NLTE) model atmospheres.

Spectral lines of xenon were also found in planetary nebulae (PN). Péquignot & Baluteau (1994) analysed lines of Xe III and Xe IV in PN spectra and found that, as a consequence of *s*-process nucleosynthesis in the PN progenitor stars, Xe abundance arrived up to 20 times solar abundance. Otsuka & Tajitsu (2013) reported the discovery of Xe III spectral lines in extremely metal-poor halo PN H4-1, explaining its presence as a result of the *r* processes in primordial supernovae, which is an additional indication of the presence of xenon in various ionization stages in stellar plasma originated from such material.

Besides astrophysical applications, Stark broadening of Xe lines in various ionization stages is of interest for laboratory plasma (Peláez et al. 2009), light sources based on Xe plasma (Seidel et al. 2001; Wieser et al. 1997) or a plasma with Xe addition or impurities, design of Xe lasers (Seidel et al. 2001) and research of laser produced plasma with Xe spectral lines (Richou & Molitor 1970; Seidel et al. 2001), and also for investigation of inertial fusion plasma (Gaisinski & Oks 1983; Keane et al. 1990), since Xe might be an impurity changing properties of such plasma.

From the point of view of inertial fusion plasma conditions, Stark broadening data not only for Xe VIII but for spectral lines of xenon in various ionization stages, is of particular interest for recent experimental and theoretical studies (Kondo et al. 2008, 2009) of shock waves, driven by a compact pulls device at 40 km s^{-1} into xenon gas. Ryutov et al. (1999) stated that such experiments with high-power lasers 'contribute to check the astrophysical computer codes and to bridge a gap between laboratory experiments and astronomical phenomena by scaling laws' (Kondo et al. 2008). In fig. 2 in Kondo et al. (2009) one can see that depending on the position behind the shock wave front, xenon ions in various ionization stages up to Xe XI are present and the Xe VIII is particularly important in the wide area.

In order to provide the Stark broadening parameters for Xe VIII spectral lines, missing in the existing literature, Stark full widths at half intensity maximum (FWHM) *W* and shift *d* for 60 transitions have been calculated by using semiclassical perturbation method (SCP; Sahal-Bréchot 1969a,b). The obtained results are also used to investigate the influence of Stark broadening, in comparison to thermal Doppler broadening, on spectral lines in DO white dwarf atmospheres.

2 THE IMPACT SEMICLASSICAL PERTURBATION METHOD

The semiclassical perturbation formalism, used here for the theoretical determination of Stark broadening parameters, has been described in details with different innovations and optimizations in Sahal-Bréchot (1969a), Sahal-Bréchot (1969b), Sahal-Bréchot (1974), Sahal-Bréchot (1991), Dimitrijević, Sahal-Bréchot & Bommier (1991), Dimitrijević & Sahal-Bréchot (1996), Sahal-Bréchot, Dimitrijević & Ben Nessib (2014). Since it is described shortly in earlier works, only brief details needed for understanding of the way of calculations and for the adequate usage of the obtained results will be given here.

For isolated lines, the Stark broadened profile $F(\omega)$ is Lorentzian:

$$F(\omega) = \frac{W/2\pi}{(\omega - \omega_{\mathrm{if}} - d)^2 + (W/2)^2}. \tag{1}$$

Here,

$$\omega_{\mathrm{if}} = \frac{E_{\mathrm{i}} - E_{\mathrm{f}}}{\hbar},$$

where E_{i} and E_{f} are energies of the initial and final states, (W) is width (FWHM) in angular frequency units and (d) shift

$$W = N \int \upsilon f(\upsilon) \mathrm{d}\upsilon \left(\sum_{i' \neq i} \sigma_{ii'}(\upsilon) + \sum_{f' \neq f} \sigma_{ff'}(\upsilon) + \sigma_{\mathrm{el}} \right)$$

$$d = N \int \upsilon f(\upsilon) \mathrm{d}\upsilon \int_{R_3}^{R_{\mathrm{D}}} 2\pi \rho \mathrm{d}\rho \sin(2\varphi_{\mathrm{p}}). \tag{2}$$

N is here the electron density, $f(\upsilon)$ the Maxwellian velocity distribution function for electrons, ρ the impact parameter of the incoming electron, and with i', f' are denoted the perturbing levels of the initial and final state. The inelastic cross-section $\sigma_{jj'}(\upsilon), j = i, f$

$$\sum_{i' \neq i} \sigma_{ii'}(\upsilon) = \frac{1}{2} \pi R_1^2 + \int_{R_1}^{R_{\mathrm{D}}} 2\pi \rho d\rho \sum_{i' \neq i} P_{ii'}(\rho, \upsilon), \tag{3}$$

where $P_{jj'}(\rho, \upsilon),\ j = i,\ f;\ j' = i',\ f'$ is transition probability. The elastic cross-section is

$$\sigma_{\mathrm{el}} = 2\pi R_2^2 + \int_{R_2}^{R_{\mathrm{D}}} 2\pi \rho d\rho \sin^2 \delta + \sigma_{\mathrm{r}},$$

$$\delta = \left(\varphi_p^2 + \varphi_q^2 \right)^{\frac{1}{2}}. \tag{4}$$

The phase shifts due to the polarization potential φ_{p} (r^{-4}) and to the quadrupolar potential φ_{q} (r^{-3}), are defined in section 3 of Chapter 2 in Sahal-Bréchot (1969a). All the cut-offs $R_1, R_2,\ R_3$, and the Debye radius R_{D} are explained in section 1 of Chapter 3 in Sahal-Bréchot (1969b). Finally, the contribution of Feshbach resonances is denoted as σ_{r} (Fleurier, Sahal-Bréchot & Chapelle 1977).

The involved approximations are discussed in detail in Sahal-Bréchot, et al. (2014) and here we will only provide the basic informations for better understanding of the used theoretical approach. The semiclassical approximation, namely the radiating atom (A) is described quantum mechanically and it is surrounded by the bath (B) of the perturbers (electrons or positive ions), which are classical particles, moving along a classical path which is not influenced by the interactions with the emitter. The electrons are moving along hyperbolic paths under the influence of attractive Coulomb force. For ionic perturbers the hyperbolic paths are different because they are influenced by the repulsive Coulomb force. The corresponding formulae for the Stark broadening parameters are analogous to equations (2)–(4), but without the contribution of Feshbach resonances.

The perturbation approximation is also used, which means that the atom-perturber interaction is treated by the time-dependent

Table 1. This table gives electron-, proton-, and doubly charged helium-impact broadening parameters for Xe VIII lines, for a perturber density of 10^{17} cm^{-3} and temperatures from 20 000 to 500 000 K. Calculated wavelength of the transitions (in Å) and parameter C are also given. This parameter, when divided with the corresponding Stark width, gives an estimate for the maximal pertuber density for which the line may be treated as isolated. W_e: electron-impact full width at half-maximum of intensity, d_e: electron-impact shift, W_p: proton-impact full width at half-maximum of intensity, d_p: proton-impact shift, $W_{He^{++}}$: doubly charged helium ion-impact full width at half-maximum of intensity, $d_{He^{++}}$: doubly charged helium ion-impact shift. This table is available in its entirety for 60 Xe VIII transitions in machine-readable form in the online journal as additional data. A portion is shown here for guidance regarding its form and content.

Transition	T(K)	W_e (Å)	d_e (Å)	W_{H^+} (Å)	d_{H^+} (Å)	$W_{He^{++}}$ (Å)	$d_{He^{++}}$ (Å)
5s $^2S_{1/2}$ – 5p $^2P^o_{1/2}$	20 000.	0.656E-02	0.401E-03	0.300E-05	−0.278E-05	0.578E-05	−0.477E-05
858.6 Å	50 000.	0.414E-02	0.112E-04	0.119E-04	−0.781E-05	0.234E-04	−0.150E-04
C= 0.86E+20	100 000.	0.293E-02	−0.344E-04	0.317E-04	−0.160E-04	0.628E-04	−0.318E-04
	200 000.	0.210E-02	−0.390E-04	0.706E-04	−0.309E-04	0.140E-03	−0.618E-04
	300 000.	0.174E-02	−0.349E-04	0.100E-03	−0.429E-04	0.199E-03	−0.858E-04
	500 000.	0.141E-02	−0.473E-04	0.135E-03	−0.602E-04	0.269E-03	−0.121E-03
5s $^2S_{1/2}$ - 5p $^2P^o_{3/2}$	20 000.	0.497E-02	0.177E-03	0.248E-05	−0.170E-05	0.478E-05	−0.292E-05
740.5 Å	50 000.	0.317E-02	0.515E-05	0.980E-05	−0.478E-05	0.194E-04	−0.917E-05
C= 0.64E+20	100 000.	0.224E-02	−0.211E-04	0.259E-04	−0.979E-05	0.513E-04	−0.194E-04
	200 000.	0.161E-02	−0.248E-04	0.567E-04	−0.191E-04	0.113E-03	−0.382E-04
	300 000.	0.134E-02	−0.221E-04	0.797E-04	−0.268E-04	0.159E-03	−0.537E-04
	500 000.	0.108E-02	−0.295E-04	0.106E-03	−0.382E-04	0.211E-03	−0.765E-04

perturbation theory. The bath of perturbers B is described by its unperturbed density operator or distribution function in the classical picture, without taking into account the amount of energy and polarization diffusing into it from emitter A, which is the no-back reaction approximation. We also suppose that the bath B is in a stationary state, and that the bath of colliding perturbers is decoupled from the bath of photons. One of the key approximations is the impact approximation which is valid if the interactions are separated in time, so that the radiator interacts with one perturber only at a given time. In other words the mean duration of an interaction must be much smaller than the mean interval between two collisions. Additionally, the complete collision approximation is introduced, assuming that atom-radiation and atom-perturber interactions are decoupled. This means that collisions are considered as instantaneous i.e. the interaction process is completed before the emission of a photon. The validity of the complete redistribution approximation is also assumed, so that the calculation of the line profile and of the populations is decoupled, which means that the radiation is weak and the atom-radiation interaction may be treated within the second-order perturbation theory. Finally the Markov approximation is also made, which means that the time evolution of emitter A (t) depends only on the time t and is not dependent on its past history.

3 STARK BROADENING PARAMETER CALCULATIONS

By means of the code based on semiclassical perturbation theory we have calculated widths and shifts for 60 transitions of Xe VIII. The needed energy levels have been taken from Saloman (2004). Oscillator strengths have been calculated by using the method of Bates & Damgaard (1949) and the tables of Oertel & Shomo (1968). For higher levels, oscillator strengths have been calculated according to Van Regemorter, Hoang Binh & Prud'homme (1979).

The complete obtained results are given in electronic form in the online journal as additional data (Table S). Here, in Table 1, only a sample of the results is provided in order to demonstrate the content of additional data and their form. The calculations of Stark widths (FWHM) and shifts for electron- proton- and doubly charged helium-impact broadening, have been performed for a perturber density of 10^{17} cm^{-3} and for a set of temperatures from 20 000 to 500 000 K.

We warn that wavelengths given in Table 1 are calculated ones, and consequently different from experimental ones. This is not of importance for the calculation of Stark broadening parameters, depending on relative and not absolute positions of energy levels and they are correct in angular frequency units. The transformation of Stark width in Å to the width expressed in angular frequency units may be performed using the following formula:

$$W(\AA) = \frac{\lambda^2}{2\pi c} W(s^{-1}), \tag{5}$$

where c is the speed of light. If the width or shift should be corrected for the difference between calculated and experimental wavelength, this can be performed for the width and in the similar manner for the shift as

$$W_{\rm cor} = \left(\frac{\lambda_{\rm exp}}{\lambda}\right)^2 W. \tag{6}$$

Here, with $W_{\rm cor}$ is denoted the corrected width, $\lambda_{\rm exp}$ is the experimental, λ the calculated wavelength and W the width from Table 1, or Table S. A similar formula can be used for the shifts.

In Tables 1 and S, a parameter C (Dimitrijević & Sahal-Bréchot 1984), giving an estimate for the maximal perturber density for which the line may be treated as isolated, when it is divided by the corresponding full width at half-maximum, is also specified. If we denote with V the collision volume and multiply it by the perturber density N, for each value given in Table $NV < 0.1$, so that this product is much less than one and the impact approximation is valid (Sahal-Bréchot 1969a,b). For $NV > 0.5$ the impact approximation breaks down and the corresponding values of Stark broadening parameters are not given. For $0.1 < NV \leq 0.5$ Stark broadening parameters are preceded by an asterisk in order to draw attention that the impact approximation reaches his limit of validity. For the plasma parameter (T and N) values for which the impact approximation is not valid, the ion broadening contribution may be estimated by using the quasi-static approach (Griem 1974; Sahal-Bréchot 1991). In the region where neither impact nor quasi-static approximation are valid, a unified-type theory should be used. We

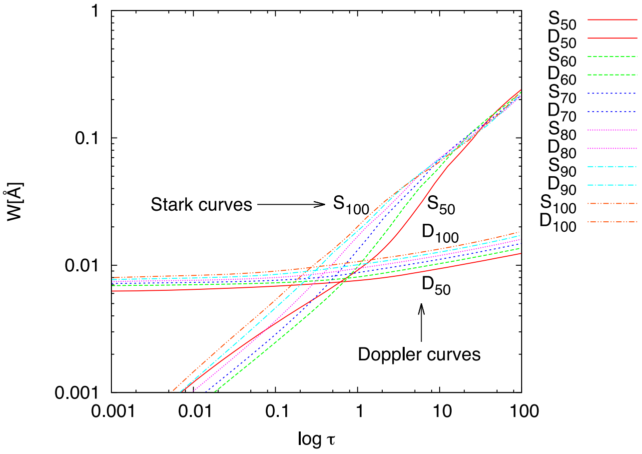

Figure 1. Stark and Doppler widths for Xe VIII 5s $^2S_{1/2}$ – 5p $^2P^o_{1/2}$ ($\lambda = 858.6$ Å) spectral line as a function of logarithm of Rosseland optical depth (log τ). Stark (S) and Doppler (D) widths are shown for six atmospheric models (Wesemael 1981) with effective temperatures from $T_{\rm eff} = 50\,0000$ K (S_{50}, D_{50}) to 100 000 K (S_{100}, D_{100}), and log $g = 9$.

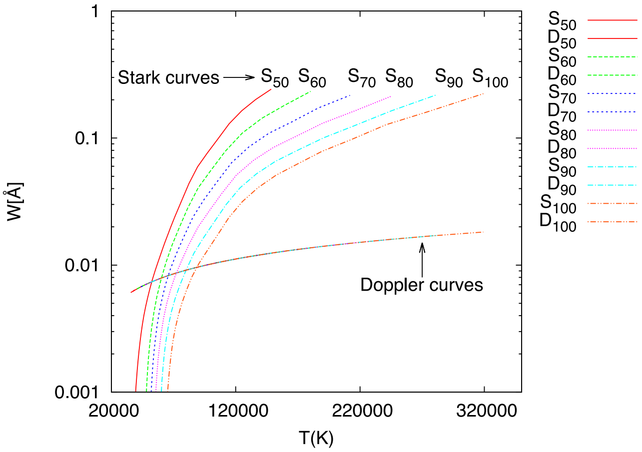

Figure 2. Stark and Doppler widths for Xe VIII 5s $^2S_{1/2}$ – 5p $^2P^o_{1/2}$ ($\lambda = 858.6$ Å) spectral line as a function of atmospheric layer temperatures. Stark (*S*) and Doppler (*D*) widths are shown for six atmospheric models (Wesemael 1981) with effective temperatures from $T_{\rm eff} = 50\,0000$ K (S_{50}, D_{50}) to 100 000 K (S_{100}, D_{100}), and log $g = 9$. We note that Doppler curves overlap.

draw attention to the paper of Barnard, Cooper & Smith (1974) where a simple analytical formula is given for such a case.

Since spectral lines of highly charged xenon ions (Xe VI and Xe VII) have been observed in DO white dwarfs (Dreizler & Werner 1996) where Stark broadening is usually dominant line broadening mechanism, we used the obtained results to investigate the importance of Stark broadening in DO white dwarf atmospheres. DO white dwarfs are a class of helium-rich white dwarfs with effective temperature 40 000 K < $T_{\rm eff}$ < 120 000 K (see e.g. Dreizler & Werner (1996)). The importance of Stark broadening in DO white dwarf atmospheres is illustrated by comparison of Stark and Doppler line widths in Figs 1–4.

In Fig. 1 Stark (FWHM) and Doppler widths for Xe VIII 5s $^2S_{1/2}$–5p $^2P^o_{1/2}$ ($\lambda = 858.6$ Å) spectral line as a function of logarithm of Rosseland optical depth, are compared for six atmospheric models of Wesemael (1981) with effective temperature $T_{\rm eff} = 50\,000$–100 000 K and logarithm of surface gravity log $g = 9$.

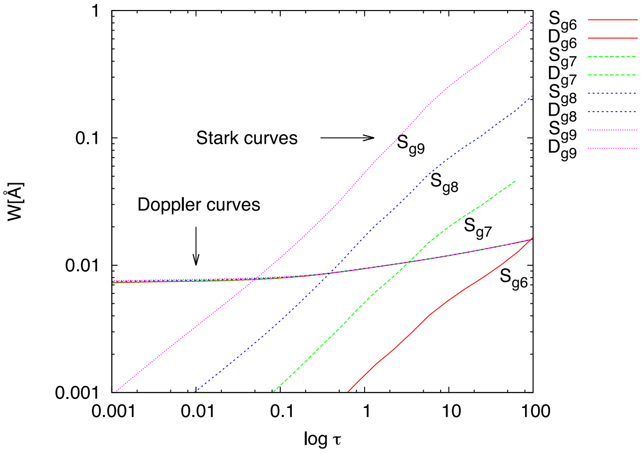

Figure 3. Stark and Doppler widths for Xe VIII 5s $^2S_{1/2}$ – 5p $^2P^o_{1/2}$ ($\lambda = 858.6$ Å) spectral line as a function of logarithm of Rosseland optical depth (log τ). Stark (*S*) and Doppler (*D*) widths are shown for four atmospheric models (Wesemael 1981) with surface gravity from log $g = 6$ (S_{g6}, D_{g6}) to 9 (S_{g9}, D_{g9}), and $T_{\rm eff} = 80\,000$ K. We note that Doppler curves overlap.

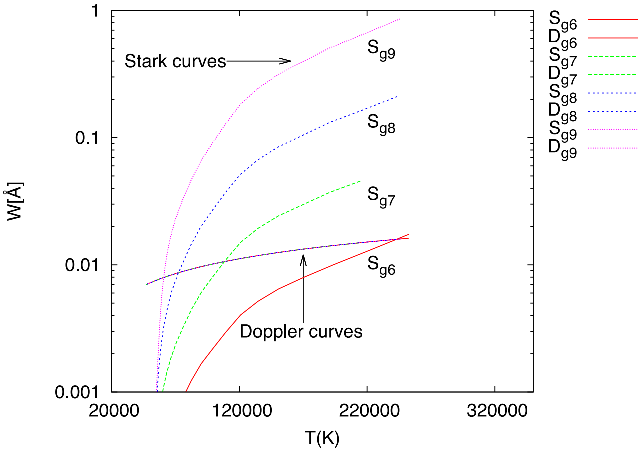

Figure 4. Stark and Doppler widths for Xe VIII 5s $^2S_{1/2}$ – 5p $^2P^o_{1/2}$ ($\lambda = 858.6$ Å) spectral line as a function of atmospheric layer temperatures. Stark (*S*) and Doppler (*D*) widths are shown for four atmospheric models (Wesemael 1981) with surface gravity from log $g = 6$ (S_{g6}, D_{g6}) to 9 (S_{g9}, D_{g9}), and $T_{\rm eff} = 80\,000$ K. We note that Doppler curves overlap.

We can see that Stark broadening is more important or comparable to Doppler broadening for important layers and that its significance increases with the increase of the optical depth. One should note that even when the Doppler width is larger than Stark width, due to the differences between Gaussian and Lorentzian profiles, Stark broadening may be important in line wings. In Fig. 2 Stark (FWHM) and Doppler widths for the same spectral line, are shown as functions of atmospheric layer temperatures, for the same atmospheric models of Wesemael (1981) used in Fig. 1. One can see that Stark broadening is dominant in comparison with Doppler broadening and that its importance increases with the increase of layer temperature as well as of effective temperature. The influence of surface gravity is shown in Figs 3 and 4, where Stark and Doppler widths, for Xe VIII 5s $^2S_{1/2}$ – 5p $^2P^o_{1/2}$ ($\lambda = 858.6$ Å) spectral line are compared in models of DO white dwarf atmospheres with surface gravity log $g = 6, 7, 8$ and 9 and $T_{\rm eff} = 80\,000$ K. They are plotted in Fig. 3 as a function of the logarithm of Rosseland optical depth and in Fig. 4 as a function of the atmospheric layer temperature. One can see that for higher values of surface gravity (log $g = 8$–9), Stark broadening is significantly larger than Doppler one for all important parts of atmosphere. For stellar atmospheres with the lowest of considered surface gravities with log $g = 6$, Stark broadening is comparable to Doppler broadening only for deep atmospheric layers.

We note that Wesemael (1981) provides LTE models and that both NLTE and line-blanketing effects should be included to obtain correct values for the line widths, like for example in Werner et al. (2003). However, only models of Wesemael (1981) are tabulated with all the needed data for calculation. Since the influence of Stark broadening, demonstrated in Figs 1–4 is convincingly dominant, the modifications due to NLTE effects and line-blanketing may modify the results but will not change our conclusions.

The obtained Stark broadening parameters for Xe VIII spectral lines, which are presented in the online Table S, in computer readable form, will be also implemented in the STARK-B data base (Sahal-Bréchot, Dimitrijević & Moreau 2015a; Sahal-Bréchot et al. 2015b), devoted to diagnostics, modelling and investigations of stellar atmospheres, diagnostics of laboratory plasmas, and investigation, analysis and modelling of laser produced, inertial fusion plasma and for plasma technologies. STARK-B is a part of Virtual Atomic and Molecular Data Center - VAMDC (Dubernet et al. 2010; Rixon et al. 2011).

4 CONCLUSIONS

We have performed a semiclassical perturbation calculation of Stark broadening parameters for 60 transitions in Xe VIII. Stark widths and shifts have been calculated for collisions of Xe VIII ions with electrons, protons and He III ions and will be imported in STARK-B data base, as a contribution to creation of an as-large-as-possible set of such data, of significance for a number of problems in astrophysical, laboratory, laser produced, inertial fusion and technological plasmas. Additionally, an analysis of the importance of Stark broadening mechanism for Xe VIII lines in DO white dwarf atmospheres has been performed demonstrating its significance for DO white dwarfs and showing that this importance increases with surface gravity, effective temperature and temperature of the atmospheric layer.

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REFERENCES

Barnard A. J., Cooper J., Smith E. W., 1974, J. Quant. Spectrosc. Radiat. Transfer, 14, 1025
Bates D. R., Damgaard A., 1949, Phil. Trans. R. Soc. A, 242, 101
Beauchamp A., Wesemael F., Bergeron P., 1997, ApJS, 108, 559
Bidelman W. P., 1962, AJ, 67, 111
Csillag L., Dimitrijević M. S., 2004, Appl. Phys. B, 78, 221
Dimitrijević M. S., 2003, Astron. Astrophys. Trans., 22, 389
Dimitrijević M. S., Sahal-Bréchot S., 1984, J. Quant. Spectrosc. Radiat. Transfer, 31, 301
Dimitrijević M. S., Sahal-Bréchot S., 1996, Phys. Scr., 54, 50
Dimitrijević M. S., Sahal-Bréchot S., 2014, Atoms, 2, 357
Dimitrijević M. S., Sahal-Bréchot S., Bommier V., 1991, A&AS, 89, 581
Dimitrijević M. S., Ryabchikova T., Popović L. Č., Shulyak D., Tsymbal V., 2003a, A&A, 404, 1099
Dimitrijević M. S., Jovanović P., Simić Z., 2003b, A&A, 410, 735
Dimitrijević M. S., Dačić M., Cvetković Z., Simić Z., 2004, A&A, 425, 1147
Dimitrijević M. S., Ryabchikova T., Popović L. Č., Shulyak D., Khan S., 2005, A&A, 435, 1191
Dimitrijević M. S., Ryabchikova T., Simić Z., Popović L. Č., Dačić M., 2007, A&A, 469, 681
Dimitrijević M. S., Kovačević A., Simić Z., Sahal-Bréchot S., 2011, Balt. Astron., 20, 580
Dreizler S., Werner K., 1996, A&A, 314, 217
Dubernet M. L. et al., 2010, J. Quant. Spectrosc. Radiat. Transfer, 111, 2151
Dufour P., Ben Nessib N., Sahal-Bréchot S., Dimitrijević M. S., 2011, Balt. Astron., 20, 511
Dworetsky M. M., Persaud J. L., Patel K., 2008, MNRAS, 385, 1523
Fleurier C., Sahal-Bréchot S., Chapelle J., 1977, J. Quant. Spectrosc. Radiat. Transfer, 17, 595
Gaisinsky I. M., Oks E. A., 1983, Energy Levels and Transition Probabilities in Atoms and Ions. Akad. Nauk SSSR, Ot. Ob. Fiz. Astron., Nauch. Sov. Spektrosk., Moscow, p. 212
Gornushkin I. B., King L. A., Smith B. W., Omenetto N., Winefordner J. D., 1999, Spectrochim. Acta B, 54, 1207
Griem H. R., 1974, Spectral line Broadening by Plasmas. McGraw-Hill, New York
Griem H. R., 1992, Phys. Fluids B, 4, 2346
Hamdi R., Ben Nessib N., Milovanović N., Popović L. Č., Dimitrijević M. S., Sahal-Bréchot S., 2008, MNRAS, 387, 871
Hamdi R., Ben Nessib N., Sahal-Bréchot S., Dimitrijević M. S., 2014, Adv. Space Res., 54, 1223
Hoffman J., Szymański Z., Azharonok V., 2006, in Marek J. Sadowski, Michel Dudek, Hans-Jrgen Hartfuss, Ewa Pawelec., eds., AIP Conf. Proc. Vol. 812, PLASMA-2005 Conference on Research and Application of Plasmas. Am. Inst. Phys., New York, p. 469
Keane C. J. et al., 1990, Rev. Sci. Instrum., 61, 2780
Kondo K., Nakajima M., Kawamura T., Horioka K., 2008, J. Phys: Conf. Ser., 112, 042028
Kondo K., Nakajima M., Kawamura T., Horioka K., 2009, Nucl. Instrum. Methods Phys. Res. A, 606, 223
Konjević N., 1999, Phys. Rep., 316, 339
Lanz T., Dimitrijević M. S., Artru M. C., 1988, A&A, 192, 249
Larbi-Terzi N., Sahal-Bréchot S., Ben Nessib N., Dimitrijević M. S., 2012, MNRAS, 423, 766
Milovanović N., Dimitrijević M. S., Popović L. Č., Simić Z., 2004, A&A, 417, 375
Oertel G. K., Shomo L. P., 1968, ApJS, 16, 175
Otsuka M., Tajitsu A., 2013, ApJ, 778, 146
Peláez R. J., Ćirišan M., Djurović S., Aparicio J. A., Mar S., 2009, A&A, 507, 1697
Péquignot D., Baluteau J.-P., 1994, A&A, 283, 593
Popović L. Č., Dimitrijević M. S., Ryabchikova T., 1999a, A&A, 350, 719
Popović L. Č., Dimitrijević M. S., Tankosić D., 1999b, A&AS, 139, 617
Popović L. Č., Milovanović N., Dimitrijević M. S., 2001a, A&A, 365, 656
Popović L. Č., Simić S., Milovanović N., Dimitrijević M. S., 2001b, ApJS, 135, 109
Rauch T., Ziegler M., Werner K., Kruk J. W., Oliveira C. M., Van de Putte D., Mignani R. P., Kerber F., 2007, A&A, 470, 317
Richou J., Molitor A., 1970, C. R. Acad. Sci. B, 271, 753

Rixon G. et al., 2011, in Lebedev V., Feigel'man M., eds., AIP Conf. Proc. Vol. 1134, 7th International Conference on Atomic and Molecular Data and their Applications-ICAMDATA-2010. Am. Inst. Phys., New York, p. 107

Ryutov D. D., Drake R. P., Kane J., Liang E., Remington B. A., Wood-Vasey W. M., 1999, ApJ, 518, 821

Sahal-Bréchot S., 1969a, A&A, 1, 91

Sahal-Bréchot S., 1969b, A&A, 2, 322

Sahal-Bréchot S., 1974, A&A, 35, 319

Sahal-Bréchot S., 1991, A&A, 245, 322

Sahal-Bréchot S., Dimitrijević M. S., Ben Nessib N., 2014, Atoms, 2, 225

Sahal-Bréchot S., Dimitrijević M. S., Moreau N., 2015a, STARK-B Database, LERMA, Observatory of Paris, France and Astronomical Observatory: Belgrade, Serbia. Available at: http://stark-b.obspm.fr

Sahal-Bréchot S., Dimitrijević M. S., Moreau N., Ben Nessib N., 2015b, Phys. Scr., 50, 054008

Saloman E. B., 2004, J. Phys. Chem. Ref. Data, 33, 765

Seidel S., Wrubel Th., Roston G., Kunze H.-J., 2001, J. Quant. Spectrosc. Radiat. Transfer, 71, 703

Simić Z., Dimitrijević M. S., Popović L. Č., Dačić M., 2005a, J. Appl. Spectrosc., 72, 443

Simić Z., Dimitrijević M. S., Milovanović N., Sahal-Bréchot S., 2005b, A&A, 441, 391

Simić Z., Dimitrijević M. S., Popović L. Č., Dačić M., 2006, New Astron., 12, 187

Simić Z., Dimitrijević M. S., Kovačević A., 2009, New Astron. Rev., 53, 246

Simić Z., Dimitrijević M. S., Sahal-Bréchot S., 2013, MNRAS, 432, 2247

Simić Z., Dimitrijević M. S., Popović L. Č., 2014, Adv. Space Res., 54, 1231

Sorge S., Wierling A., Röpke G., Theobald W., Sauerbrey R., Wilhein T., 2000, J. Phys. B, 33, 2983

Tankosić D., Popović L. Č., Dimitrijević M. S., 2003, A&A, 399, 795

Torres J., van de Sande M. J., van der Mullen J. J. A. M., Gamero A., Sola A., 2006, Spectrochim. Acta B, 61, 58

Van Regemorter H., Hoang Binh Dy., Prud'homme M., 1979, J. Phys. B, 12, 1073

Werner K., Deetjen J. L., Dreizler S., Nagel T., Rauch T., Schuh S. L., 2003, in Hubeny I., Dimitri M., Klaus W., eds., ASP Conf. Ser. Vol. 288, Stellar Atmosphere Modeling. Astron. Soc. Pac., San Francisco, CA, p. 31

Werner K., Rauch Th., Ringat E., Kruk J. W., 2012, ApJ, 753, L7

Wesemael F., 1981, ApJS, 45, 177

Wieser J., Murnick D. E., Ulrich A., Huggins H. A., Liddle A., Brown W. L., 1997, Rev. Sci. Instrum., 68, 1360

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table 1. This table gives electron-, proton-, and doubly charged helium-impact broadening parameters for Xe VIII lines, for a perturber density of 10^{17} cm^{-3} and temperatures from 20 000 to 500 000 K.
(http://www.mnras.oxfordjournals.org/lookup/suppl/doi:10.1093/mnras/stv1970/-/DC1).

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